

## **3. Identification and Screening of General Response Actions and Remedial Technologies**

### **3.1. Overview and Evaluation of Screening Process**

This chapter evaluates and screens several response actions and remedial technologies capable of achieving the Remedial Action Objectives (RAOs) identified in Chapter 2. Section 3.2 describes General Response Actions available to address the RAOs. Section 3.3 screens remedial technologies and process options that may be included in the General Response Actions based on applicability, effectiveness, implementability, and cost. Various actions and technologies that pass the screening may be combined to form the potentially viable remediation modules presented in Chapter 4. The modules are subsequently combined into alternative remedies in Chapter 6. Section 3.4 discusses the use of innovative technologies for remediation. Section 3.5 presents a summary of the technologies retained through this screening process. All technologies evaluated in the technology screening process are described in Appendix C.

### **3.2. General Response Actions**

General Response Actions describe those actions that can potentially achieve the RAOs established in Chapter 2. These actions are intended to: (1) mitigate potential exposure to, (2) control the migration of, and/or (3) remediate contaminants of concern identified in Chapter 1. Eight General Response Actions have been identified for OUs or release sites at Site 300.

2. No Further Action
3. Risk and Hazard Management
4. Monitored Natural Attenuation
5. Extraction with *Ex situ* Treatment
6. *In situ* Treatment
7. Containment
8. Hydraulic Control
9. Removal and Disposal

Table 3-1 summarizes the potential response actions for each RAO for Site 300. For the discussion below, some response actions have been combined since they are, in practice, integrated.

#### **3.2.1. No Further Action**

In CERCLA feasibility studies, a no-action alternative provides a basis for comparison with other remedial actions. All ongoing activities would cease under this response. Natural

degradation, dispersion, adsorption, dilution, and volatilization are the only processes that would take place, and will occur regardless of intervention.

### **3.2.2. Risk and Hazard Management**

Risk and hazard management may include institutional, administrative, and ventilation controls, as well ecological resource surveys, and can be used as a General Response Action to mitigate exposure to contaminated media. This General Response Action is used primarily in areas where risk exceeds  $10^{-6}$ , and may be acceptable as the sole response action when the risk falls in the  $10^{-6}$  to  $10^{-4}$  risk range. This General Response Action may also be used when hazard management measures can adequately protect human health or ecological receptors from exposure to hazards that might otherwise exceed a Hazard Index of one. Risk and hazard management may commonly be employed in conjunction with other actions, such as monitoring or active responses.

#### **3.2.2.1. Institutional/Administrative Controls**

Institutional and administrative controls may be used as a means of risk management to restrict some or all access to, and thereby mitigate exposure to, hazards in a contaminated area. These controls can involve a range of measures, from simply posting signs and installing fences, to regulated restrictions on the use of property. Also included are the use of operational safety procedures, developed for all remedial activities, to ensure worker safety and the proper handling of all hazardous materials. Administrative measures can have the effect of limiting human activities or access or restricting use of contaminated water. These measures help to mitigate potential exposure pathways.

The following administrative controls are already in place at Site 300 and are expected to be maintained:

- Site 300 access restricted and controlled by fencing and a full time security force.
- Building occupancy and land use controlled by Site 300 Management.
- Additional controls on access to areas outside of regular work areas.
- Safety briefing required of all personnel working at Site 300, which discusses access requirements and areas of contamination.
- There are no drinking water wells on site, and any new water supply wells of any kind are subject to review, with environmental considerations in mind.
- Operational Safety Plans are required for all construction activities which includes checks for hazardous materials and sensitive species.
- A wildlife biologist reviews proposals for all land-disturbing activities, and recommends ecological protection measures if appropriate.

#### **3.2.2.2. Ventilation Controls**

Ventilation controls, such as engineered ventilation of buildings where unacceptable inhalation risk for VOCs exist, can disperse VOCs. If the VOCs are dispersed adequately, long-term inhalation risk can be reduced to an acceptable level.

### **3.2.2.3. Ecological Hazard Controls**

This response action would involve enhancement of LLNL's ongoing ecological resource survey program to ensure that sensitive species are not negatively impacted by planned ground-disturbing activities. As currently implemented, any area proposed for an activity that causes significant surface disturbance (e.g., well installation or facility construction) must be surveyed by a wildlife biologist for the presence of sensitive species. If sensitive species are present, then mitigation measures as defined in the EIS/EIR would be implemented. This program to mitigate impacts to wildlife will be expanded to include monitoring of those areas in which the relevant ecological Hazard Index exceeds 1.

Currently, the only threatened, endangered, or species of special concern that may be potentially exposed to unacceptable levels of contaminants are predatory fossorial species (i.e., San Joaquin kit fox, American badger, burrowing owl, etc.). Thus, areas where the ecological Hazard Index for the San Joaquin kit fox exceeds 1 will be monitored for the presence of sensitive predatory fossorial species. Should kit fox or other predatory fossorial species of special concern to wildlife agencies be found in these areas, the DOE will consult with the appropriate wildlife agency to develop response actions, such as monitoring, collection of additional characterization data, or possibly animal relocation. An exception to this is for areas where PCBs/CDDs are present in surface soil. These areas will be monitored for the presence of any threatened, endangered or species of special concern.

In addition, biologists will monitor Site 300 for the presence of sensitive species not previously identified at Site 300. The life history of these species will be reviewed to determine the potential for unacceptable exposure to contaminants present at the site. Should it be determined that these species do have a potential risk of significant exposure, their presence in areas where Hazard Indices exceed 1 (such as those for ground squirrels or deer) will be determined. Finally, environmental contaminant data will be monitored to ensure site conditions with respect to contamination do not change to such an extent as to threaten other wildlife populations for plant communities.

There are no actual surface waters for which the current hazard indices exceed 1. Spring 5, at which the concentration of VOCs still exceeds the PRG, has no surface flow. Modeling of contaminated surface water in the baseline ecological assessment showed this pathway did not present a significant exposure to vertebrate species or aquatic animals. For the SWRI, comparisons were made between contaminated sites and reference (uncontaminated) sites, and those showed no difference in species diversity indices between sites. Thus, general response actions for ecological receptors for surface water were not developed.

### **3.2.3. Monitored Natural Attenuation**

Monitored natural attenuation (MNA) has long been recognized as an option for contaminant reduction in the environment, and has proven effective in certain contaminants (e.g., fuel hydrocarbons and relatively short half-lived radionuclides). Recent studies have demonstrated that degradation, a major component of natural attenuation, is a significant factor in observed concentration decreases of chlorinated solvents, HE compounds, and many other contaminants. Degradation may be either biotic (e.g., by subsurface microbes) or abiotic (e.g., by hydrolysis). Laboratory and theoretical considerations lead to the conclusion that HE compounds and other

inorganic compounds at Site 300 may also degrade in a time frame of years to decades. Examples include nitrate, which is broken down by organisms in the root zone of plants, to be either released as nitrogen gas or incorporated into cell structures; and perchlorate, which is sufficiently reactive in the subsurface that it is unlikely to migrate significantly in naturally buffered subsurface materials. Metals may change valence state or become biologically unavailable through a variety of processes in such a way as to reduce risks. More persistent organic pollutants, such as PCBs, degrade slowly with time and change into less toxic forms. However, the time frame may preclude use of MNA for certain compounds.

In the monitored natural attenuation General Response Action, risk reduction occurs through natural degradation, decay, adsorption, volatilization, and evapotranspiration. Attenuation may also occur from dilution and dispersion, although these mechanisms may not be appropriate as the only remediation alternative. MNA is potentially applicable to VOCs, nitrate, perchlorate, certain inorganic compounds, tritium, and HE compounds. Under this response action, monitoring data are collected and reviewed to determine the natural decline of contaminant concentrations. Computer modeling incorporates aquifer parameters and chemical properties to predict the reduction of subsurface contamination over time.

MNA would typically be instituted in conjunction with a specific monitoring plan for upgradient, interior plume, and guard wells. There must be no threat from an active source and human health must be protected. Risk and hazard management may be implemented as part of the program. The DOE has controls already in place to prevent public use or access of Site 300 and has no plans to release lands from their stewardship, and would never do so without full concurrence regarding cleanup. An OU-specific contingency plan may be written if the site-wide contingency plan has not yet been prepared or needs to be supplemented to cover site-specific issues. Contingent remedial actions would be implemented if conditions specified in the contingency plan are not met (e.g., contaminant concentrations increase or are not reducing as projected to meet ARARs). The DOE will submit a general Site 300 Contingency Plan in 2002, which will address MNA issues.

According to EPA policy Directive 9200.4-17, the elements important to establishing an MNA remedy are: (1) contamination currently not posing an unacceptable risk, (2) source control, and (3) static or retreating plume contours. Natural attenuation may be demonstrated through a variety of lines of evidence, including static or retreating plume concentration contours, parent or breakdown products, or the depletion or formation of geochemical indicator compounds.

This SWFS retains MNA as a remedial alternative where degradation can be currently demonstrated—namely for tritium (with an established half-life of 12.3 years) and for VOCs at Landfill Pit 6 (where TCE breakdown products have appeared and historical monitoring shows a downward trend in TCE concentration). Where modeling of uranium fate and transport shows that activities should diminish to below the MCL within a timeframe comparable to other feasible remediation options, MNA has also been evaluated. MNA is retained as an option for further consideration at other OUs, when data on degradation rates and concentration reductions become available. For instance, LLNL is currently researching the degradation mechanisms and rates for HE compounds. MNA may be particularly applicable following an active remedy, if concentrations from a pump and treat alternative become asymptotic.

### **3.2.4. Extraction with *Ex situ* Treatment**

Removal of subsurface contamination in ground water and/or soil vapor may involve extraction of the contaminated media followed by treatment and discharge of the treated fluid. This response action follows EPA's 'presumptive response strategy' to permanently remove contaminants from the site.

Ground water extraction generally consists of pumping from either wells or trenches. Passive siphon technology may also be used to extract ground water. Volatile contaminants can be removed from unsaturated soils by soil vapor extraction, which usually consists of applying a vacuum to one or more wells screened in the vadose zone. Ground water and soil vapor may be extracted from the same wells through simultaneous or dual-phase extraction systems. In some extraction scenarios, the removal of ground water may expose a greater volume of unsaturated soil from which to extract soil vapor.

Innovative extraction technologies include methods that help to mobilize and/or remove contaminants from ground water and/or soil/rock. Possible extraction alternatives or enhancement methods include surfactant injection, steam flooding, joule heating, electro-osmosis, hot air injection, and passive soil vapor extraction. These methods can be used in conjunction with ground water extraction and/or soil vapor extraction (SVE).

Ex situ treatment methods separate, destroy, or convert contaminants in extracted ground water or soil vapor, vapor by-products from ground water treatment systems, or soil. Possible ex situ ground water treatment methods include sorption to aqueous-phase granular activated carbon (GAC), air sparging/air stripping, ultraviolet (UV)/oxidation, ion exchange, coupled chemical/biological treatment, bioremediation, phytoremediation, zero valent iron filings treatment, and constructed wetlands. Possible ex situ vapor treatments include vapor-phase GAC sorption, thermal oxidation, catalytic oxidation, resin sorption, UV/oxidation, and vapor-phase electron beam destruction. EPA has identified most of these as 'presumptive treatment technologies.'

If treatment only separates the contaminant, such as sorption onto GAC or ion exchange resin, the contaminant would then either be properly disposed of at a licensed facility or further treated. Typically GAC would be thermally treated at an off-site facility to destroy the sorbed contaminants. Contaminants are flushed from resins which are then reused and the contaminated brine treated at an off-site facility.

Methods for disposal of treated ground water include discharge to surface water, sanitary sewers, storm drains, sewage treatment pond, on-site surface discharge, reinjection, on-site recycling/reuse, off-site uses, and air misting. The method for disposal of treated air emissions is discharge to the atmosphere.

### **3.2.5. *In situ* Treatment**

In situ treatment methods destroy or convert contaminants in ground water and/or soil/rock to less toxic compounds. Possible in situ methods are air sparging, permeable reactive barriers, enhanced in situ bioremediation of organic contaminants, and in situ phytoremediation.

### 3.2.6. Containment and/or Hydraulic Control

As a General Response Action, physical containment and/or hydraulic controls can be used to control the migration or mobilization of contaminants. The action can be directed at containing a ground water contaminant plume or preventing recharge water from creating or spreading ground water contamination. Containment can also help control soil vapor migration via soil vapor extraction, or prevent offsite flow of contaminated surface waters.

Below-ground physical barriers (i.e., ground water containment systems constructed of low-permeability materials such as slurry walls and grout curtains or hydraulic barriers created by injection of treated ground water) prevent or severely restrict the flow of ground water and contaminants. These subsurface barriers can be installed at or near plume margins to inhibit further migration of contaminants primarily in the horizontal direction.

Interceptor trenches, surface covers, and ground water interceptor system methods are used to reroute recharge water or leachate and restrict the flow of ground water and contaminants. Surface covers can also retard leaching of contaminants from the soil to ground water.

Physical barriers alone, while they may be protective of human health and the environment, would result in relatively slow contaminant (e.g., VOC) removal by natural degradation compared to more active alternatives. Physical barriers are commonly used in combination with extraction techniques, such as pumping or in situ treatment. The depth or lateral extent of ground water contamination can limit the implementability of containment or cause containment to be too expensive to consider as a viable alternative.

Hydraulic control of tritium plumes by extracting ground water from the leading edge of a tritium plume and re-injecting upgradient was evaluated. The re-circulation process as a remedial measure for hydraulic control of the tritium plumes poses the following problems:

1. The re-injection of tritiated water into areas with clean ground water would result in the increase in the extent of contamination in ground water.
2. Re-injection tritiated water near the source area could increase the hydraulic gradient and could spread of the existing contaminated waters into clean areas further and faster than without such injection.
3. The re-injection of tritiated water in areas where ground water is present at shallow depths, such as the Pits 3&5 area, could exacerbate the inundation of the source area during periods of high rainfall and result in further contaminant releases.
4. Short-term human health and ecological risks are increased by bringing tritium to the surface.

The portion of the tritium plumes with activities above drinking water standards (20,000 pCi/L) is currently stable and the tritium plumes do not currently pose a risk to human or ecological receptors. Due to concerns that hydraulic control through re-circulation could further mobilize or spread the plume, and increase risk, this general response action was not retained as a primary remedial measure for the tritium plume at this time.

However, re-injection was retained as a component for remedial measures that extract and treat ground water containing multiple contaminants such as VOCs, nitrate, perchlorate, and tritium. It would be necessary under this type of remedial scenario, following treatment of the

VOCs and other contaminants for which a viable treatment technology exists, to re-inject the tritiated water. In addition, safety precautions would need to be implemented to prevent exposure to tritium during the extraction and re-injection process. The efficacy of this remedial strategy would depend on the volume and tritium levels in the water to be re-injected, as well as the re-injection location. Modeling would need to be conducted prior to implementation of this type of remedial action to ensure that re-injection would not result in inundation of a source area and/or further mobilization of the tritium plume. If the modeling results indicate that the re-injection of even limited volumes of water could potentially result in further releases and/or the spread of the tritium plume, the implementability of this remedial strategy may be limited.

Waste in landfills can potentially be immobilized by injection and mixing of stabilizing agents. The injection and mixing of stabilizing agents (Appendix C-1.6.3.) is still in development as an innovative technology. This approach is retained for future consideration.

### **3.2.7. Removal and Disposal**

Source removal involves a complex process of locating, characterizing, excavating, treating, and/or disposing of contaminated waste, soil, rock, and/or debris. A number of tasks must be completed to implement a source removal General Response Action. These tasks may include:

1. Preparing work and safety plans.
2. Conducting preliminary borehole and geophysical surveys.
3. Constructing a waste storage facility and a general staging facility for decontamination.
4. Administrative activities.
5. Excavating source material.
6. Waste characterization.
7. Temporary waste storage.
8. Waste transportation.
9. Off-site or on-site treatment, destruction, or disposal.
10. Protection of the public, workers, and the environment from chemical, radiological, and physical hazards.

Excavation may include partial or total waste removal as necessary to control contaminant sources and prevent further releases to the environment. Excavated source material would be transported to an off-site permitted facility for treatment, destruction, and/or disposal.

On-site containment is also being considered as a potentially lower cost alternative to disposing excavated source material at a permitted off-site disposal/treatment facility. On-site containment would involve designing and constructing an engineered containment unit with components to prevent releases of contaminants.

Two options for siting an on-site containment unit have been identified. A containment unit could be constructed at the location of an existing landfill pit(s) or alternatively, at a new location in a "clean," uncontaminated area.

A detailed discussion of waste disposal options and associated considerations/limitations is presented in Section C-2.7 of Appendix C.

### **3.3. Evaluation and Screening of Remedial Technologies and Process Options**

This report evaluates one or more technologies that were considered to be potentially viable for each General Response Action. These technologies were evaluated against four criteria: applicability, effectiveness, implementability, and cost.

In the first step of the technology screening process, technologies were evaluated for their applicability to the media and contaminants of concern at Site 300. Table 3-2 lists the General Response Actions and technologies by the media and contaminants of concern at Site 300 to which they apply.

The applicable technologies were evaluated to determine their effectiveness in remediating the media and contaminants of concern given the technologies' limitations. The applicable and effective technologies were then assessed for the implementability of the technology at the OUs and release sites given specific site conditions. The technologies considered to be implementable at one or more OU or release site were retained for an evaluation of the cost of the technology.

From the cost evaluation, we retained technologies which were considered to be applicable, effective, and implementable, and for which the costs were estimated to be low to medium. If the cost of a technology was considered to be high, but no other available technology exists to remediate the media and contaminants of concern at Site 300, the technology was retained. If the cost of a technology was high to very high and other lower cost technologies were available, the technology was not retained.

Tables 3-3, 3-4, 3-5, and 3-6 summarize the screening and evaluation of General Response Actions, technology types, and process options available for the remedial alternatives for ground water, vadose zone, surface soil and surface water, respectively.

The first column of Tables 3-3, 3-4, 3-5, and 3-6 lists the General Response Actions. Listed with each General Response Action are one or more technologies that are considered potentially viable. These tables document the reasons for retaining or eliminating a technology from further consideration, based on the criteria of applicability, effectiveness, implementability, and cost. The last column indicates whether the technology was retained for consideration in the development of the remediation modules (presented in Chapter 4 of this report). Section 3.4 addresses innovative technologies.

### **3.4. Innovative Technologies**

Although we evaluated several innovative technologies in the screening process, most are not considered technically feasible at this time and are not used in the development of the remediation modules in Chapter 4. However, the option of testing and/or implementing new technologies for Site 300 OUs and release sites is retained. This option is consistent with DOE objectives of conducting environmental remediation projects to allow better, faster, and more cost effective treatment options to be tested and used in the future. In addition, DOE will continue to review the development of technologies for the treatment of tritium for which no currently viable treatment technology has been identified.

### **3.5. Summary of Retained Technologies**

Through the development and screening of General Response Actions and remedial technologies, numerous actions and technologies have been retained. Table 3-7 summarizes the retained technologies for ground water, vadose zone, surface soil, and surface water at Site 300. Each of these technologies was considered during development of the modules discussed in Chapter 4 and combined into alternative remedies in Chapter 6. Retained technologies that were incorporated into the remediation modules were chosen based on applicability, implementability, effectiveness, cost, site-specific requirements, and professional experience.

**Table 3-1. Potential general response actions to achieve remedial action objectives.**

Remedial Action Objective	Potential General Response Actions
<b>For Human Health Protection:</b>	
1. Prevent human ingestion of ground water and surface water containing contaminant concentrations (single carcinogen) above the State and federal drinking water Maximum Contaminant Levels (MCLs).	<ul style="list-style-type: none"> <li>- No further action</li> <li>- Risk and hazard management</li> <li>- Monitored natural attenuation</li> <li>- Ground water extraction with <i>ex situ</i> treatment</li> <li>- Ground water <i>in situ</i> treatment</li> <li>- Hydraulic control</li> <li>- Disposal</li> </ul>
2. Prevent human incidental ingestion and direct dermal contact with contaminants in surface soil that pose an excess cancer risk greater than $10^{-6}$ or a hazard index (HI) greater than 1, a cumulative excess cancer risk (all carcinogens) in excess of $10^{-4}$ , or cumulative HI (all noncarcinogens) greater than 1.	<ul style="list-style-type: none"> <li>- No further action</li> <li>- Risk and hazard management</li> <li>- Containment</li> <li>- Removal and disposal</li> </ul>
3. Prevent human inhalation of VOCs and tritium volatilizing from subsurface soil to air that pose an excess cancer risk greater than $10^{-6}$ or a HI greater than 1, a cumulative excess cancer risk (all carcinogens) in excess of $10^{-4}$ , or cumulative HI (all noncarcinogens) greater than 1.	<ul style="list-style-type: none"> <li>- No further action</li> <li>- Risk and hazard management</li> <li>- Soil vapor extraction with treatment (VOCs)</li> <li>- Containment</li> <li>- Removal and disposal</li> </ul>
4. Prevent human inhalation of contaminants (VOCs and tritium) volatilizing from surface water to air that pose an excess cancer risk greater than $10^{-6}$ or HI greater than 1, a cumulative excess cancer risk (all carcinogens) in excess of $10^{-4}$ , or cumulative HI (all noncarcinogens) greater than 1.	<ul style="list-style-type: none"> <li>- No further action</li> <li>- Risk and hazard management</li> <li>- Containment</li> </ul>
5. Prevent human inhalation of contaminants bound to resuspended surface soil particles that pose an excess cancer risk greater than $10^{-6}$ or HI greater than 1, a cumulative excess cancer risk (all carcinogens) in excess of $10^{-4}$ , or cumulative HI (all noncarcinogens) greater than 1.	<ul style="list-style-type: none"> <li>- No further action</li> <li>- Risk and hazard management</li> <li>- Containment</li> <li>- Removal and disposal</li> </ul>

**Table 3-1. Potential general response actions to achieve remedial action objectives. (Cont. Page 2 of 2)**

Remedial Action Objective	Potential General Response Actions
<b><i>For Environmental Protection:</i></b>	
1. Restore water quality, at a minimum, to water quality objectives which are protective of beneficial uses.	<ul style="list-style-type: none"> <li>- No further action</li> <li>- Monitored natural attenuation</li> <li>- Ground water extraction and <i>ex situ</i> treatment</li> <li>- Ground water <i>in situ</i> treatment</li> <li>- Soil vapor extraction and treatment (VOCs)</li> <li>- Hydraulic control</li> <li>- Removal and disposal</li> </ul>
2. Ensure ecological receptors important at the individual level of organization (listed threatened or endangered, State of California species of special concern) do not reside in areas where relevant ecological hazard indices exceed 1.	<ul style="list-style-type: none"> <li>- No further action</li> <li>- Risk and hazard management</li> </ul>
3. Ensure existing contaminant conditions do not change so as to threaten wildlife populations and vegetation communities.	<ul style="list-style-type: none"> <li>- No further action</li> <li>- Risk and hazard management</li> </ul>

Table 3-2. Potential general response actions and technologies by contaminant and media.

Contaminant	Ground water		Vadose zone		Surface soil		Surface water	
	General response action	Technology	General response action	Technology	General response action	Technology	General response action	Technology
VOCs	<u>No further action:</u>	None	<u>No further action:</u>	None	<u>No further action:</u>	None	<u>No further action:</u>	- None
	<u>Risk and hazard management:</u>	- Administrative controls (e.g., water-use prohibitions)	<u>Risk and hazard management:</u>	- Administrative controls (e.g., fencing, land use restrictions) - Re-engineered ventilation system - Ecological hazard controls	<u>Risk and hazard management:</u>	- Administrative controls (e.g., fencing, land use restrictions) - Ecological hazard controls	<u>Risk and hazard management:</u>	- Administrative controls (e.g., fencing, water use restrictions)
	<u>Monitored natural attenuation:</u>	- Ground water sampling and analysis; water level measurements; modeling	<u>Extraction with ex situ treatment:</u>	- Induced soil vapor extraction (SVE) - Passive SVE - Dual-phase extraction - Simultaneous ground water extraction/SVE - Thermally enhanced SVE (i.e., steam flooding, joule heating)	<u>Removal and disposal:</u>	- Soil/rock removal - Waste removal - Soil treatment and/or disposal - Waste treatment and/or disposal		
	<u>Extraction with ex situ treatment:</u>							
	Ground water extraction:	- Ground water pumping or siphoning from wells - Ground water pumping or siphoning from trenches - Extraction using funnel and gate with a collector basin - Surfactant injection - Electro-osmosis	Ex situ treatment:	- Vapor-phase GAC - Thermal oxidation - Catalytic oxidation - UV/Oxidation-vapor phase - Resin sorption - Electron accelerator - vapor phase				
	Ex situ treatment:	- Aqueous-phase granular activated carbon (GAC) - Air sparging + vapor-phase GAC - Air stripping + vapor-phase GAC - Aqueous-phase ultraviolet (UV)/oxidation - Coupled chemical/biological treatment - Bioremediation - Zero valent iron filings	Disposal of treated vapor:	- Permitted discharge to ambient air of treated vapor				
			Disposal of treatment waste:	- Spent GAC recycling/disposal offsite				

Table 3-2. Potential general response actions and technologies by contaminant and media. (Cont. Page 2 of 7)

Contaminant	Ground water		Vadose zone		Surface soil		Surface water	
	General response action	Technology	General response action	Technology	General response action	Technology	General response action	Technology
VOCs (cont.)	Disposal of treated water:	<ul style="list-style-type: none"><li>- Permitted discharge to surface water</li><li>- Permitted discharge to sanitary sewer or storm drain</li><li>- Permitted discharge to sewage pond</li><li>- On-site surface discharge</li><li>- Permitted reinjection</li><li>- On-site recycling/reuse</li><li>- Air misting</li></ul>	<u>Containment:</u>	<ul style="list-style-type: none"><li>- Asphalt surfacing</li><li>- Synthetic membrane liner</li><li>- Capping</li></ul>				
	Disposal of treatment waste:	<ul style="list-style-type: none"><li>- Off-site uses</li><li>- Off-site recycling/disposal of spent GAC/ iron filings, etc.</li></ul>						
	<u>In situ treatment:</u>	<ul style="list-style-type: none"><li>- Air sparging</li><li>- Permeable reactive barrier</li><li>- Enhanced <i>in situ</i> bioremediation</li></ul>		<u>Removal and disposal:</u>				
	<u>Containment:</u>	<ul style="list-style-type: none"><li>- Slurry walls</li><li>- Grout curtain</li></ul>		<ul style="list-style-type: none"><li>- Soil/rock removal</li><li>- Soil/rock disposal</li></ul>				
	<u>Hydraulic control:</u>	<ul style="list-style-type: none"><li>- Surface cover/pit capping</li><li>- Ground water interceptor system</li><li>- Interceptor trenches</li></ul>						
TBOS/TKEBs	<u>No further action:</u>	<ul style="list-style-type: none"><li>- None</li></ul>	NA	NA	NA	NA	NA	NA
	<u>Monitored natural attenuation:</u>	<ul style="list-style-type: none"><li>- Ground water sampling and analysis; water level measurements; modeling</li></ul>						
	<u>Ground water extraction with ex situ treatment:</u>							
	Ground water extraction:	<ul style="list-style-type: none"><li>- Ground water pumping or siphoning from wells</li></ul>						
	<i>Ex situ</i> treatment:	<ul style="list-style-type: none"><li>- Gravity separation/skimming</li><li>- Aqueous-phase GAC</li><li>- Air stripping</li></ul>						

Table 3-2. Potential general response actions and technologies by contaminant and media. (Cont. Page 3 of 7)

Contaminant	Ground water		Vadose zone		Surface soil		Surface water	
	General response action	Technology	General response action	Technology	General response action	Technology	General response action	Technology
TBOS/TKEBs (Cont.)	Disposal of treated water:	<ul style="list-style-type: none"><li>- Permitted discharge to surface water</li><li>- Permitted discharge to sanitary sewer or storm drain</li><li>- Permitted discharge to sewage pond</li><li>- On-site surface discharge</li><li>- Permitted reinjection</li><li>- On-site recycling/reuse</li><li>- Air misting</li></ul>						
	Disposal of treatment waste:	<ul style="list-style-type: none"><li>- Off-site recycling/disposal</li><li>- Off-site recycling/reuse</li></ul>						
HE Compounds	<u>No further action:</u>	- None	<u>No further action:</u>	- None	NA	NA	NA	NA
	<u>Monitored natural attenuation:</u>	- Ground water sampling and analysis; water level measurements; modeling	<u>Monitored natural attenuation:</u>	- Ground water sampling and analysis; water level measurements; modeling				
	<u>Ground water extraction with ex situ treatment:</u>							
	Ground water extraction:	- Ground water pumping or siphoning from wells	<u>Treatment:</u>	- No practicable technologies identified				
	Ex situ treatment:	<ul style="list-style-type: none"><li>- Aqueous-phase GAC</li><li>- Phytoremediation</li><li>- Constructed wetlands</li><li>- Coupled biological/chemical treatment</li></ul>	<u>Removal and disposal:</u>	<ul style="list-style-type: none"><li>- Soil/rock removal</li><li>- Soil/rock disposal</li></ul>				
	Disposal of treated water:	<ul style="list-style-type: none"><li>- Permitted discharge to surface water</li><li>- Permitted discharge to sanitary sewer or storm drain</li><li>- Permitted discharge to sewage pond</li><li>- On-site surface discharge</li><li>- Permitted reinjection</li><li>- On-site recycling/reuse</li><li>- Air misting</li><li>- Off-site uses</li></ul>						

Table 3-2. Potential general response actions and technologies by contaminant and media. (Cont. Page 4 of 7)

Contaminant	Ground water		Vadose zone		Surface soil		Surface water	
	General response action	Technology	General response action	Technology	General response action	Technology	General response action	Technology
HE Compounds (Cont.)	Disposal of treated waste:	<ul style="list-style-type: none"><li>- On-site recycling/reuse</li><li>- Air misting</li><li>- Off-site disposal of spent GAC</li></ul>						
Perchlorate	<u>No further action:</u>	- None	<u>No further action:</u>	- None	NA	NA	NA	NA
	<u>Monitored natural attenuation:</u>	<ul style="list-style-type: none"><li>- Ground water sampling and analysis; water level measurements; modeling</li></ul>						
	<u>Ground water extraction with ex situ treatment:</u>							
	Ground water extraction:	<ul style="list-style-type: none"><li>- Ground water pumping or siphoning from wells</li></ul>	<u>Treatment:</u>	<ul style="list-style-type: none"><li>- No practicable technologies identified</li></ul>				
	Ex situ treatment:	<ul style="list-style-type: none"><li>- Aqueous phase GAC</li><li>- Ion exchange</li><li>- Coupled biological/chemical</li><li>- Bioremediation (bioreactor)</li><li>- Phytoremediation</li></ul>	<u>Removal and disposal:</u>	<ul style="list-style-type: none"><li>- Excavation</li><li>- Soil/rock disposal</li></ul>				
	Disposal of treated water:	<ul style="list-style-type: none"><li>- Permitted discharge to surface water</li><li>- Permitted discharge to sanitary sewer or storm drain</li><li>- Permitted discharge to sewage pond</li><li>- On-site surface discharge</li><li>- Permitted reinjection</li><li>- On-site recycling/reuse</li><li>- Air misting</li><li>- Off-site uses</li></ul>			NA	NA	NA	NA
	Disposal of treated waste:	<ul style="list-style-type: none"><li>- Off-site recycling/disposal of spent GAC</li><li>- Off-site recycling of spent resin</li><li>- Off-site disposal of brine</li></ul>						
Nitrate	<u>No further action:</u>	None	<u>No further action:</u>	- None	NA	NA	NA	NA
	<u>Monitored natural attenuation:</u>	<ul style="list-style-type: none"><li>- Ground water sampling and analysis; water level measurements; modeling</li></ul>						
	<u>Ground water extraction with ex situ treatment:</u>							

Table 3-2. Potential general response actions and technologies by contaminant and media. (Cont. Page 5 of 7)

Contaminant	Ground water		Vadose zone		Surface soil		Surface water	
	General response action	Technology	General response action	Technology	General response action	Technology	General response action	Technology
Nitrate (Cont.)	Ground water extraction:	- Ground water pumping or siphoning from wells	<u>Treatment:</u>	- No practicable technologies identified				
	<i>Ex situ</i> treatment:	- Ion exchange (resin sorption) - Zero valent iron filings - Bioremediation (bioreactor) - Phytoremediation - Constructed wetland	<u>Removal and disposal:</u>	- Soil/rock removal - Soil/rock disposal				
	Disposal of Treated Water:	- Permitted discharge to surface water - Permitted discharge to sanitary sewer or storm drain						
	Disposal of Treated Waste:	- Permitted discharge to sewage pond - On-site surface discharge - Permitted reinjection - On-site recycling/reuse - Air misting - Off-site uses - Off-site recycling/disposal of spent resin - Off-site disposal of brine						
Metals	NA	NA	NA	NA	<u>No further action:</u> <u>Risk and hazard management:</u>  <u>In situ treatment:</u> <u>Containment</u> <u>Removal and disposal:</u>	- None - Administrative/engineered controls (i.e., fencing, land use restrictions) - Ecological hazards control - Phytoremediation - Capping - Soil excavation/removal - Soil disposal	NA	NA
PCBs, CDDs, and CDFs	NA	NA	NA	NA	<u>No further action:</u>  <u>Risk and hazard management:</u>	None  - Administrative/engineered controls (i.e., fencing, land use restrictions) - Ecological hazards control	NA	NA

Table 3-2. Potential general response actions and technologies by contaminant and media. (Cont. Page 6 of 7)

Contaminant	Ground water		Vadose zone		Surface soil		Surface water	
	General response action	Technology	General response action	Technology	General response action	Technology	General response action	Technology
PCBs, CDDs, and CDFs (cont.)	NA	NA	NA	NA	<u>Removal and disposal:</u>	- Soil excavation/removal - Soil disposal		
Tritium	<u>No further action:</u>	None	<u>No Further Action:</u>	- None	<u>No further action:</u>	- None	<u>No further action:</u>	- None
	<u>Monitored natural attenuation:</u>	- Ground water sampling and analysis; water level measurements; modeling	<u>Treatment:</u>	- No safe, proven technologies available	<u>Risk and hazard management:</u>	- Administrative/engineered controls (i.e., fencing, land use restrictions) - Ecological hazards control	<u>Risk and hazard management:</u>	- Administrative controls (i.e., fencing, land use restrictions)
	<u>Ground water extraction with ex situ treatment:</u>		<u>Containment:</u>	- Capping	<u>Treatment</u>	- No safe, proven technologies available	<u>Containment</u>	- Collection and disposal
	Ground water extraction:	- Ground water pumping or siphoning from wells - Ground water pumping or siphoning from trenches	<u>Removal and disposal:</u>	- Soil/rock removal - Soil/rock disposal - Waste disposal	<u>Containment</u> <u>Removal and disposal:</u>	- Capping - Soil excavation/removal - Soil disposal - Waste disposal		
	Treatment:	- No safe, proven technologies identified						
	<u>Containment:</u>	- Slurry wells - Grout curtain						
	<u>Hydraulic control:</u>	- Surface cover/pit capping - Ground water interceptor system						
	<u>Disposal of untreated water:</u>	- Disposal at offsite facility						
Uranium	<u>No further action:</u>	None	<u>No further action:</u>	- None	<u>No further action:</u>	None	NA	NA
	<u>Ground water extraction with ex situ treatment:</u>							
	Ground water extraction:	- Ground water pumping or siphoning from wells - Ground water pumping or siphoning from trenches	<u>Monitored natural attenuation:</u>	- Soil/rock sampling and analysis; modeling	<u>Risk and hazard management:</u>	- Administrative/engineered controls (i.e. fencing, land use restrictions) - Ecological hazards control		
	<u>Ex situ treatment:</u>	- Ion exchange	<u>Treatment:</u>	- No practicable technologies identified	<u>Removal and disposal:</u>	- Soil/waste excavation/removal - Soil disposal - Waste disposal		
	Disposal of treated water:	- Permitted discharge to surface water - On-site surface discharge - Reinjection - Air misting						
	Disposal of	- Off-site recycling of spent resin						

Table 3-2. Potential general response actions and technologies by contaminant and media. (Cont. Page 7 of 7)

Contaminant	Ground water		Vadose zone		Surface soil		Surface water	
	General response action	Technology	General response action	Technology	General response action	Technology	General response action	Technology
	treatment waste:	- Off-site disposal of brine						
Uranium (Cont.)	<u>In situ treatment:</u>	- Permeable reactive barrier	<u>Removal and disposal:</u>	- Excavation - Soil disposal				
	<u>Containment:</u>	- Slurry walls - Grout curtain - In situ stabilization						
	<u>Hydraulic control:</u>	- Surface cover/pit capping - Ground water interceptor system - Interceptor trenches						

Notes:  
GAC = Granular activated carbon.  
GWE = Ground water extraction.  
NA = Not applicable; contaminant not present in media.  
SVE = Soil vapor extraction.

**Table 3-3. Preliminary response action screening and evaluation for ground water.**

General response action	Remediation technology type	Technology (process options)	Screening comments	Effectiveness	Implementability	Cost	Retained
<u>No further action</u>	None	Natural decay, degradation, dispersion, adsorption, dilution, volatilization, and/or evapotranspiration.	Applicable.	Limited effectiveness.	Implementable.	No cost	For comparison only
<u>Risk and hazard management:</u>							
Administrative controls:	Limit access to ground water	Access control	Applicable.	Effective on site.	Implementable.	Very low	Yes
	Point-of-use water-supply treatment	GAC treatment	Not applicable.	Effective.	Implementable.	Low	Yes <sup>a</sup>
<u>Monitored natural attenuation</u>	Ground water sampling and analysis; water level measurement; modeling	Natural degradation, decay dispersion, adsorption, dilution, volatilization, and/or evapotranspiration.	Applicable.	Effective for contaminants that naturally attenuate within a reasonable timeframe.	Implementable.	Low	Yes

**Table 3-3. Preliminary response action screening and evaluation for ground water. (Cont. Page 2 of 10)**

General response action	Remediation technology type	Technology (process options)	Screening comments	Effectiveness	Implementability	Cost	Retained
<b><u>Extraction with ex situ treatment:</u></b>							
<b>Extraction</b>	<b>Ground water extraction</b>	<b>Ground water pumping or siphoning from wells</b>	<b>Applicable.</b>	<b>Effective under favorable hydrogeologic conditions when combined with treatment. Provides hydraulic control of contaminant plume.</b>	<b>Implementable. Already being implemented at Building 834 OU. To be implemented at HE Process Area and Building 832 Canyon OUs in near future.</b>	<b>Low to moderate</b>	<b>Yes</b>
		<b>Ground water pumping or siphoning from trenches</b>	<b>Applicable. Long cleanup times.</b>	<b>Potentially effective in areas with narrow confined plumes. Treatment required. Provides hydraulic control of contaminant plume.</b>	<b>Implementable with other technologies. Not practical due to presence of bedrock; requires excavation. Plume control can be achieved with ground water extraction wells.</b>	<b>NCF</b>	<b>No</b>
		<b>Extraction using funnel and gate with a collector basin.</b>	<b>Applicable. Effective capture of upgradient contaminant plume. One extraction well.</b>	<b>Can be effective in aquifers with little drawdown potential and high concentrations.</b>	<b>Implementable with other technologies. Not practical at Site 300 because other ground water pumping would not be avoided.</b>	<b>NCF</b>	<b>No</b>

**Table 3-3. Preliminary response action screening and evaluation for ground water. (Cont. Page 3 of 10)**

General response action	Remediation technology type	Technology (process options)	Screening comments	Effectiveness	Implementability	Cost	Retained
<b><u>Extraction with ex situ treatment (cont.):</u></b>							
<b>Extraction (cont.)</b>	<b>Contaminant surface tension reduction/mobilization</b>	<b>Surfactant injection</b>	<b>Applicable when combined with ground water extraction. Innovative technology.</b>	<b>Effective for VOCs but can increase mobility of DNAPLs.</b>	<b>Implementable. Difficult to ensure capture of surfactants and mobilized DNAPLs. May increase risk of further vertical migration of contaminants.</b>	<b>NCF</b>	<b>No</b>
		<b>Electro-osmosis</b>	<b>Applicable when combined with ground water extraction. Innovative technology.</b>	<b>Effective for VOCs in low permeability sediments.</b>	<b>Requires detailed characterization, bench scale experimentation, and site-specific design.</b>	<b>Low to medium</b>	<b>Yes<sup>a</sup></b>
<b>Treatment</b>	<b>Ex situ ground water treatment</b>	<b>Gravity separation/skimming</b>	<b>Applicable for TBOS/TKEBS.</b>	<b>Effective for TBOS/TKEBS.</b>	<b>Implementable.</b>	<b>Low</b>	<b>Yes</b>

**Table 3-3. Preliminary response action screening and evaluation for ground water. (Cont. Page 4 of 10)**

General response action	Remediation technology type	Technology (process options)	Screening comments	Effectiveness	Implementability	Cost	Retained
<b><u>Extraction with ex situ treatment (cont.):</u></b>							
<b>Treatment (cont.)</b>	<b>Ex situ ground water treatment (cont.)</b>	<b>GAC sorption—aqueous phase</b>	<b>Applicable for both remediation and point-of-use (POU) treatment.</b>	<b>Effective for most VOCs and for HE compounds. Most appropriate for low flow rates and low VOC concentrations.</b>	<b>Implementable. Potentially high operation and maintenance (O&amp;M) due to carbonate precipitation and vessel clogging. Used carbon requires regeneration or disposal.</b>	<b>Medium</b>	<b>Yes</b>
		<b>Air sparging/air stripping</b>	<b>Applicable. Air permit required.</b>	<b>Effective for VOCs when combined with vapor-phase GAC. Possible reduced efficiency due to carbonate precipitation.</b>	<b>Implementable. Potentially high O&amp;M due to carbonate precipitation and reduced efficiency. Design to prevent scaling.</b>	<b>Medium</b>	<b>Yes</b>
		<b>GAC sorption—vapor phase</b>	<b>Applicable in conjunction with air stripping or sparging.</b>	<b>Effective for VOCs in vapor.</b>	<b>Implementable. Used carbon requires regeneration or disposal.</b>	<b>Medium</b>	<b>Yes</b>

**Table 3-3. Preliminary response action screening and evaluation for ground water. (Cont. Page 5 of 10)**

General response action	Remediation technology type	Technology (process options)	Screening comments	Effectiveness	Implementability	Cost	Retained
<b><u>Extraction with ex situ treatment (cont.):</u></b>							
Treatment (cont.)	Ex situ ground water treatment (cont.)	UV/oxidation—aqueous phase	Applicable.	Effective, destroys VOCs. Possible reduced efficiency due to carbonate precipitation, turbidity.	Implementable. High energy consumption. May require GAC polishing unit to achieve discharge requirements. High O&M costs.	High	No
		Ion exchange	Applicable for nitrates. Potentially applicable for uranium and perchlorate.	Effective for nitrates when designed for Site 300 high sulfate water. Commercially available resins will preferentially select sulfate over nitrate. Effective for Uranium.	May be implementable for nitrate-selective resins. Resin regeneration required. Disposal costs for brine are high. Separate resins for uranium. Disposal cost is high.	High for nitrate treatment  High for uranium treatment	Yes
		Coupled chemical/biological treatment	Innovative technology	Effective for HE compounds and perchlorate.	Potentially implementable.	Medium	Yes <sup>a</sup>

**Table 3-3. Preliminary response action screening and evaluation for ground water. (Cont. Page 6 of 10)**

General response action	Remediation technology type	Technology (process options)	Screening comments	Effectiveness	Implementability	Cost	Retained
<b><u>Extraction with ex situ treatment (cont.):</u></b>							
<b>Treatment (cont.)</b>	<b>Ex situ ground water treatment (cont.)</b>	<b>Bioremediation</b>	<b>Technology currently being developed for nitrates, perchlorates, VOCs and HE.</b>	<b>Effective for treatment of nitrate. VOCs, perchlorates and HE under investigation.</b>	<b>NCF for VOCs. Implementable for nitrate treatment. Pre, post or stand alone system.</b>	<b>Medium</b>	<b>Yes (for nitrate treatment only)</b>
		<b>Zero valent iron filings treatment</b>	<b>Applicable.</b>	<b>Effective for VOCs and possibly other COCs.</b>	<b>Potentially implementable.</b>	<b>Medium</b>	<b>Yes</b>
		<b>Phytoremediation</b>	<b>Applicable. Innovative technology.</b>	<b>Possibly effective for nitrate and metals.</b>	<b>Potentially implementable.</b>	<b>Low to medium</b>	<b>Yes<sup>a</sup></b>
		<b>Constructed wetlands</b>	<b>Applicable. Innovative technology.</b>	<b>Effective for HE compounds, nitrate, and perchlorate.</b>	<b>Potentially implementable.</b>	<b>Medium</b>	<b>Yes<sup>a</sup></b>
<b><u>Disposal</u></b>	<b>Treated ground water disposal</b>	<b>Permitted discharge to surface water</b>	<b>Applicable.</b>	<b>Effective.</b>	<b>Implementable. Requires permits.</b>	<b>Low to medium</b>	<b>Yes<sup>a</sup></b>

**Table 3-3. Preliminary response action screening and evaluation for ground water. (Cont. Page 7 of 10)**

<b>General response action</b>	<b>Remediation technology type</b>	<b>Technology (process options)</b>	<b>Screening comments</b>	<b>Effectiveness</b>	<b>Implementability</b>	<b>Cost</b>	<b>Retained</b>
<b><u>Disposal (cont.):</u></b>	<b>Treated ground water disposal (cont.)</b>	<b>Permitted discharge to sanitary sewer or storm drain</b>	<b>Not applicable. No public sewer system or storm drains available near Site 300.</b>	<b>NCF</b>	<b>NCF</b>	<b>NCF</b>	<b>No</b>
		<b>Permitted discharge to sewage pond</b>	<b>Applicable. Permit modification may be necessary.</b>	<b>Effective.</b>	<b>Implementable. May be limited by pond capacity.</b>	<b>Low</b>	<b>Yes<sup>a</sup></b>
		<b>On-site surface discharge</b>	<b>Applicable. Infiltration areas or irrigation spray.</b>	<b>Effective.</b>	<b>Implementable.</b>	<b>Low</b>	<b>Yes</b>
		<b>Permitted reinjection</b>	<b>Applicable. May also act to contain the plume.</b>	<b>Effective. May be used to hydraulically push contaminants toward extraction wells/trenches.</b>	<b>Must ensure that recharge does not adversely affect subsurface (e.g., migration of VOCs). Permitting required.</b>	<b>Medium to high</b>	<b>Yes<sup>a</sup></b>
		<b>On-site recycling/reuse</b>	<b>Not applicable. Inadequate demand.</b>	<b>NCF</b>	<b>NCF</b>	<b>NCF</b>	<b>No</b>
		<b>Air misting</b>	<b>Applicable.</b>	<b>Effective for low flows.</b>	<b>Implementable</b>	<b>Low</b>	<b>Yes</b>

**Table 3-3. Preliminary response action screening and evaluation for ground water. (Cont. Page 8 of 10)**

General response action	Remediation technology type	Technology (process options)	Screening comments	Effectiveness	Implementability	Cost	Retained
<b><u>Disposal (cont.):</u></b>	Treated ground water disposal (cont.)	Off-site uses	Applicable. Demand unknown.	Effective.	Dependent upon negotiations and legal issues with off-site recipients.	Unknown	No
	Spent GAC disposal	Offsite recycling/disposal	Applicable.	Effective.	Implementable.	Low	Yes
	Spent resin and brine disposal	Offsite recycling/disposal	Applicable.	Effective.	Implementable.	High	Yes
<b><u>In situ treatment:</u></b>	<i>In situ</i> ground water treatment	Air sparging	Applicable. Innovative technology.	Effectiveness for VOCs uncertain due to localized subsurface permeability heterogeneities. May increase VOC mass removal rates and reduce cleanup times.	Difficult to control movement and capture of sparged VOCs in fractured bedrock.	NCF	No
		Permeable reactive barrier	Applicable. Innovative technology.	May be effective for VOCs and uranium.	Implementable. The permeable reactive barrier alternatives may require compliance with substantive waste discharge requirements designed to ensure that residual materials or by-products protect beneficial uses.	Medium to high	Yes <sup>a</sup>

**Table 3-3. Preliminary response action screening and evaluation for ground water. (Cont. Page 9 of 10)**

General response action	Remediation technology type	Technology (process options)	Screening comments	Effectiveness	Implementability	Cost	Retained
<u>In situ treatment:</u> (cont.)		Enhanced <i>in situ</i> bioremediation	Innovative technology.	May be effective for VOCs.	Implementable. The enhanced <i>in situ</i> bioremediation alternatives may require compliance with substantive waste discharge requirements designed to ensure that residual materials or by-products protect beneficial uses.	Low to medium	Yes <sup>a</sup>
<u>Containment:</u>	Ground water containment	Slurry walls	Applicable in conjunction with ground water extraction and treatment only at areas where shallow plume depths.	Effective for horizontal source migration control in unconsolidated material due to construction constraints.	Difficult to implement. Would require excavation of bedrock in many places.	High	No
		Grout curtain	Applicable in conjunction with ground water extraction and treatment.	Effective for horizontal source migration control.	Difficult to implement.	High	No
	Waste immobilization	Injecting stabilizing agent	Innovative technology	May be effective for tritium and uranium.	Technology in development.	Medium to high	Yes <sup>a</sup>
<u>Hydraulic control:</u>	Ground water control	Surface cover/pit capping	Applicable	Effective for vertical recharge that mobilizes contaminants.	Implementable.	High	Yes

**Table 3-3. Preliminary response action screening and evaluation for ground water. (Cont. Page 10 of 10)**

General response action	Remediation technology type	Technology (process options)	Screening comments	Effectiveness	Implementability	Cost	Retained
<b>Hydraulic control: (cont.)</b>		Ground water interceptor system	Applicable.	Effective for tritium and uranium.	Difficult to implement. May not prevent ground water infiltration of pit.	Medium to high	No
		Ground water extraction and reinjection	Applicable for tritium only with extraordinary safety precautions.	May increase migration rates of highest activities.	Difficult or impossible to permit.	High	No
		Interceptor trenches	Useful for collecting contaminants in low permeability soils.	Only effective for unconsolidated materials when combined with extraction.	Implementable where contamination is shallow.	High	No

**Notes:**

DNAPL = Dense nonaqueous-phase liquid.

GAC = Granular activated carbon.

NCF = Not considered further.

O&amp;M = Operations and maintenance.

UV = Ultraviolet.

VOCs = Volatile organic compounds.

HE = High explosive.

<sup>a</sup> Retained for future consideration.

**Table 3-4. Preliminary response action screening and evaluation for the vadose zone.**

General response action	Remediation technology type	Technology (process options)	Screening comments	Effectiveness	Implementability	Cost	Retained
<b><u>No further action</u></b>	None	Natural decay, degradation, dispersion, adsorption, and volatilization.	Applicable.	Limited. Could impact ground water. May not be protective of human health and the environment.	Implementable.	No additional cost	Yes
<b><u>Risk and hazard management:</u></b>							
<b>Administrative controls:</b>	Restrict access and use	Fencing and signs	Applicable.	Effective.	Currently implemented on site.	Low	Yes
		Security guards/patrols	Applicable.	Effective.	Implementable.	Low	Yes
		Land use restrictions	Applicable.	Effective.	Currently implemented on site.	Low-medium	Yes
<b>Ventilation controls</b>	Enhanced ventilation of buildings	Re-engineered building ventilation systems	Applicable.	Effective in controlling inhalation exposure risk for VOCs in buildings. No mass removal.	Implementable.	Low	Yes <sup>a</sup>
<b>Ecological hazards control:</b>	None	Ecological surveys	Applicable.	Effective.	Currently implemented on site.	Low-medium	Yes

**Table 3-4. Preliminary response action screening and evaluation for the vadose zone. (Cont. Page 2 of 6)**

General response action	Remediation technology type	Technology (process options)	Screening comments	Effectiveness	Implementability	Cost	Retained
<b><u>Extraction with ex situ treatment:</u></b>							
<b>Extraction</b>	<b>Venting</b>	<b>Induced soil vapor extraction</b>	<b>Applicable when combined with vapor-phase GAC treatment.</b>	<b>Effective for VOC mass removal and reduction of soil vapor concentrations.</b>	<b>Implementable.</b>	<b>Low-medium</b>	<b>Yes<sup>a</sup></b>
		<b>Passive soil vapor extraction</b>	<b>Innovative technologies. Applicable when combined with treatment.</b>	<b>Effective for VOCs.</b>	<b>Implementable.</b>	<b>Low</b>	<b>Yes<sup>a</sup></b>
		<b>Dual-phase extraction</b>	<b>Applicable when combined with vapor-phase GAC treatment and ground water treatment technology.</b>	<b>Effective for VOCs, particularly for higher concentrations. Exposes greater soil column for vadose zone remedial actions.</b>	<b>Implementable. Used in conjunction with soil venting technologies.</b>	<b>Low-medium</b>	<b>Yes<sup>a</sup></b>
		<b>Simultaneous ground water and soil vapor extraction</b>	<b>Applicable when combined with vapor-phase GAC treatment and ground water treatment technology.</b>	<b>Effective for VOCs, particularly for higher concentrations. Exposes greater soil column for vadose zone remedial actions.</b>	<b>Implementable. Used in conjunction with soil venting technologies.</b>	<b>Low-medium</b>	<b>Yes</b>

**Table 3-4. Preliminary response action screening and evaluation for the vadose zone. (Cont. Page 3 of 6)**

General response action	Remediation technology type	Technology (process options)	Screening comments	Effectiveness	Implementability	Cost	Retained
<u>Extraction with ex situ treatment (cont.):</u>	Thermal enhancement	Steam flooding	Applicable. Innovative technology.	Effectiveness uncertain.	NCF	NCF	No <sup>b</sup>
	Extraction (cont.)	Joule-heating	Applicable. Innovative technology.	Effectiveness considered to be extremely localized.	NCF	NCF	No <sup>b</sup>
		Hot air injection	Applicable. Innovative application of a proven technology.	Not very effective due to low heat capacity of air.	Only implementable with special engineering efforts to allow large flow rates in compensation for low heating capacity of air.	Very high	No <sup>b</sup>
Treatment	Ex situ soil vapor treatment air emissions control	GAC—vapor phase	Applicable.	Effective for VOCs.	Implementable. Used carbon requires regeneration or disposal.	Medium	Yes
		Thermal oxidation	Applicable.	Effective. Destroys VOCs.	Implementable. Fire permit required. Fire safety concerns. May produce HCl as by-product. Requires auxiliary fuel for VOC combustion.	NCF	No

**Table 3-4. Preliminary response action screening and evaluation for the vadose zone. (Cont. Page 4 of 6)**

General response action	Remediation technology type	Technology (process options)	Screening comments	Effectiveness	Implementability	Cost	Retained
<b><u>Extraction with ex situ treatment (cont.):</u></b>							
<b>Treatment (cont.)</b>	<b>Ex situ soil vapor treatment air emissions control (cont.)</b>	<b>Catalytic oxidation</b>	<b>Not applicable.</b>	<b>Not effective for chlorinated VOCs due to production of potentially toxic by-products.</b>	<b>NCF</b>	<b>NCF</b>	<b>No</b>
		<b>UV/Oxidation—vapor phase</b>	<b>Applicable. Innovative technology.</b>	<b>Effective at destroying VOCs. Produces off-gas products.</b>	<b>Potentially implementable.</b>	<b>High</b>	<b>No</b>
		<b>Resin sorption</b>	<b>Applicable. Innovative technology.</b>	<b>Effective.</b>	<b>Potentially implementable.</b>	<b>High</b>	<b>No</b>
		<b>Electron accelerator—vapor phase</b>	<b>Applicable. Innovative technology.</b>	<b>Effective.</b>	<b>Potentially implementable. Possible high energy consumption.</b>	<b>High</b>	<b>No<sup>b</sup></b>
	<b>Treated air disposal</b>	<b>Permitted discharge to ambient air</b>	<b>Applicable.</b>	<b>Effective.</b>	<b>Implementable under San Joaquin Valley Unified Air Pollution Control Board permits.</b>	<b>Low</b>	<b>Yes</b>
	<b>Spent GAC disposal</b>	<b>Offsite recycling/disposal</b>	<b>Applicable.</b>	<b>Effective.</b>	<b>Implementable.</b>	<b>Low</b>	<b>Yes</b>

**Table 3-4. Preliminary response action screening and evaluation for the vadose zone. (Cont. Page 5 of 6)**

General response action	Remediation technology type	Technology (process options)	Screening comments	Effectiveness	Implementability	Cost	Retained
<u>In situ treatment</u>	<i>In situ</i> soil treatment	Biological enhancement	Applicable. Innovative technology.	Effectiveness unknown.	Control may be difficult due to subsurface heterogeneities.	High	Yes <sup>a</sup>
<u>Containment</u>	Surface cover	Asphalt surfacing	Applicable.	Retards leaching from soil, minimizes short circuiting of airflow from surface for SVE.	Implementable. Asphalt cover (i.e., parking lot).	Low-medium	No; already implemented where possible.
		Synthetic membrane liners	Applicable.	Minimizes short circuiting of airflow from surface, and reduces VOC flux to atmosphere.	Implementable. Surface construction.	High	No
	Capping	Engineered caps	Applicable.	Prevents venting of hazardous vapors and retards leaching from vadose zone.	Implementable. Surface construction.	High	Yes

**Table 3-4. Preliminary response action screening and evaluation for the vadose zone. (Cont. Page 6 of 6)**

General response action	Remediation technology type	Technology (process options)	Screening comments	Effectiveness	Implementability	Cost	Retained
<b><u>Removal and disposal</u></b>	Excavation	Soil/rock removal	Applicable for small, shallow volumes only.	Effective. Removes source materials. Materials would be land disposed or treated elsewhere.	Impractical in many places because excavation would include bedrock to depth.  Need to protect excavation workers from increased risk to exposure. Need to identify disposal facility to accept waste.	Very high	Yes
	Contaminated soil/rock disposal	Offsite disposal	Applicable.	Effective; however, material may have to be land disposed offsite.	Implementable.	High to very high	Yes
		Onsite disposal	Applicable.	Effective.	Implementable; may be limited by cost; hydrogeological, biological, and topographic considerations; and DOE regulations and institutional requirements.	High to very high	Yes

**Notes:**

GAC = Granular activated carbon.

NCF = Not considered further.

UV = Ultraviolet.

<sup>a</sup> VOCs = Volatile organic compounds.<sup>a</sup> Technology retained for future consideration.<sup>b</sup> May consider innovative technologies in the future.

Table 3-5. Preliminary response action screening and evaluation for surface soil.

General response action	Remediation technology type	Technology (process options)	Screening comments	Effectiveness	Implementability	Cost	Retained
<u>No further action</u>	None	Natural decay, degradation, dispersion, adsorption, and volatilization.	Applicable.	Limited. May not be protective of human health and the environment.	Implementable.	No cost	Yes
<u>Risk and hazard management:</u>							
Administrative controls	Restrict access and use	Fencing and signs	Applicable.	Effective.	Currently implemented on site.	Low	Yes
		Security guards/patrols	Applicable.	Effective.	Implementable.	Low	Yes
		Land use restrictions	Applicable.	Effective.	Currently implemented on site.	Low-medium	Yes
Ecological hazards control:	None	Ecological surveys	Applicable.	Effective.	Currently implemented on site.	Low-medium	Yes
<u>In situ treatment</u>	<i>In situ</i> soil treatment	Phytoremediation	Applicable. Innovative technology.	Effectiveness unknown.	Potentially implementable.	Low-medium	Yes <sup>a</sup>
<u>Removal and disposal</u>	Excavation	Soil/rock removal	Applicable for small volumes only	Effective. Removes source materials but not a permanent solution. Materials would be land disposed or treated elsewhere.	Implementable. Need to protect excavation workers from increased risk to exposure. Need to locate disposal facility to accept waste for treatment and/or disposal.	Medium	Yes
		Waste removal	Applicable.	Effective.	Implementable. Need to protect excavation workers from increased risk to exposure. Need to locate disposal facility to accept waste for treatment and/or disposal.	Medium	Yes
	Waste disposal	Offsite or onsite treatment and/or disposal	Applicable.	Effective.	Implementable.	High to very high	Yes
	Contaminated soil disposal	Offsite treatment and/or disposal	Applicable.	Effective.	Implementable.	Medium to high	Yes

<sup>a</sup> Retained for future consideration.

**Table 3-6. Preliminary response action screening and evaluation for surface water.**

<b>General response action</b>	<b>Remediation technology type</b>	<b>Technology (process options)</b>	<b>Screening comments</b>	<b>Effectiveness</b>	<b>Implementability</b>	<b>Cost</b>	<b>Retained</b>
<b><u>No further action</u></b>	<b>None</b>	<b>Natural decay, degradation, dispersion, adsorption, and volatilization.</b>	<b>Applicable.</b>	<b>Limited. May not be protective of human health and the environment.</b>	<b>Implementable.</b>	<b>No cost</b>	<b>For comparison only</b>
<b><u>Risk and hazard management:</u></b>							
<b>Administrative controls:</b>	<b>Restrict access and use</b>	<b>Fencing and signs</b>	<b>Applicable.</b>	<b>Effective.</b>	<b>Currently implemented on site.</b>	<b>Low</b>	<b>Yes</b>
		<b>Security guards/patrols</b>	<b>Applicable.</b>	<b>Effective.</b>	<b>Implementable.</b>	<b>Low</b>	<b>Yes</b>
		<b>Land use restrictions</b>	<b>Applicable.</b>	<b>Effective.</b>	<b>Currently implemented on site.</b>	<b>Low-medium</b>	<b>Yes</b>
<b>Containment</b>	<b>Collection of surface water</b>	<b>Water pumps Tanks</b>	<b>Applicable.</b>	<b>Not effective for tritium.</b>	<b>Difficult to implement.</b>	<b>Low-medium</b>	<b>No</b>

**Table 3-7. Retained general response actions and remedial technologies.**

General response action/ technology		
General Response Action/Technology	Applicability to contaminants of concern (COCs)	Applicability to OUs/Release Sites
<b>Ground water</b>		
<b><u>Monitored natural attenuation:</u></b>		
Ground water sampling and analysis/water levels	VOCs, tritium	Pit 6 Landfill (VOCs and tritium), B850/Pits 3 & 5 (tritium) & B854 (tritium)
<b><u>Risk and hazard management:</u></b>		
<b>Administrative control:</b>		
Access control	All COCs	Control well drilling and use of ground water
<b><u>Extraction with ex situ treatment:</u></b>		
<b>Extraction:</b>		
Extraction via siphons	VOCs	B832 Canyon
Extraction from wells	All COCs	Pit 6 Landfill, HE Process Area, B850/Pits 3 & 5 & Site-Wide OU (B801 dry well & B851 firing table only) ( <i>Others in simultaneous ground water and soil vapor extraction</i> )
Electro-osmosis	VOCs	Retained for future consideration
<b>Treatment:</b>		
Ex situ gravity separation/skimming	TBOS/TKEBS	B834
GAC sorption—aqueous phase	VOCs, TBOS/TKEBS, HE compounds	VOCs: B834, Pit 6 Landfill, HE Process Area, & Site-Wide OU (B801 dry well) TBOS/TKEBS: B834
Air stripping/sparging + GAC sorption—vapor phase	VOCs	B834, B850/Pits 3 & 5, B854, B832 Canyon, & Site-Wide OU (B833 only)
Ion exchange (resin sorption)	Uranium, nitrate, perchlorate	B850/Pits 3 & 5, & B851 firing table
Coupled biological/chemical treatment	HE compounds, perchlorate	Retained for future consideration
Bioremediation (bioreactor)	Nitrate, perchlorate	B834, HE Process Area, & B832 Canyon, B854
Zero valent iron filings treatment	VOCs	Retained for future consideration (B832 Canyon)
Phytoremediation	Nitrate, metals	B834, HE Process Area, B850/Pits 3 & 5, B854, 832, Canyon, B801, Landfill Pit 8
Constructed wetlands	HE compounds, perchlorate, nitrate	Retained for future consideration

**Table 3-7. Retained general response actions and remedial technologies.**  
**(Cont. Page 2 of 4)**

General response action/ technology		
General Response Action/Technology	Applicability to contaminants of concern (COCs)	Applicability to OUs/Release Sites
<b>Ground water (cont.)</b>		
<b><u>Extraction with ex situ treatment (cont.):</u></b>		
Disposal of treated water:		
Permitted discharge to surface water	All COCs <sup>a</sup>	Retained for future consideration
Permitted discharge to sewage pond	All COCs <sup>a</sup>	Retain for future consideration
On-site surface discharge	All COCs <sup>a</sup>	B834, Pit 6 Landfill, HE Process Area, B850/Pits 3 & 5, B854, B832 Canyon, & Site-Wide OU (B801, B833, B851 firing table)
Reinjection	All COCs <sup>a</sup>	B850/Pits 3 & 5
Air misting	All COCs <sup>a</sup>	Retained
Disposal of treatment waste:		
Off-site disposal of spent GAC	VOCs	Aqueous phase GAC: B834, Pit 6 Landfill, HE Process Area, & Site-Wide OU (B801 dry well) Vapor phase GAC: B834, B850/Pits 3 & 5, B854, B832 Canyon, & Site-Wide OU (B833 only)
Off-site disposal/regeneration spent resin and brine	Uranium	B850/Pits 3 & 5
<b><u>In situ treatment:</u></b>		
Permeable reactive barrier	Uranium	B850/Pits 3 & 5
Enhanced <i>in situ</i> bioremediation	VOCs	B834
<b><u>Containment:</u></b>		
Waste stabilization	Tritium and uranium	Retained for future consideration at Pits 3 & 5
<b>Vadose zone</b>		
<b><u>No further action</u></b> (no sampling or analysis)		HEPA, B832 Canyon, B801 & B851
<b><u>Risk and hazard management:</u></b>		
Administrative controls:		
Fencing and signs	All COCs <sup>b</sup>	Already implemented at Site 300; retained as OU-specific contingency
Security guards/patrols	All COCs <sup>b</sup>	Already implemented at Site 300; retained as OU-specific contingency

**Table 3-7. Retained general response actions and remedial technologies.**  
**(Cont. Page 3 of 4)**

General response action/ technology		
General Response Action/Technology	Applicability to contaminants of concern (COCs)	Applicability to OUs/Release Sites
<b>Vadose zone (cont.)</b>		
<b><u>Risk and hazard management (cont.):</u></b>		
Land use restrictions	All COCs <sup>b</sup>	Already implemented at Site 300; retained as OU-specific contingency
Ventilation controls	VOCs	Retained as a contingency technology (B834, B854)
Ecological hazard control	VOCs	B834, Pit 6 Landfill
Extraction:		
Induced soil vapor extraction	VOCs	Retained for future consideration
Passive soil vapor extraction	VOCs	Retained for future consideration
Dual-phase ground water and soil vapor extraction	VOCs	Retained for future consideration
Simultaneous ground water and soil vapor extraction	VOCs	B834, B854, B832 Canyon, & Site-Wide OU (B833)
Thermally enhanced soil vapor extraction	VOCs	Retained for future consideration
Treatment:		
GAC sorption—vapor phase	VOCs	B834, B854, B832 Canyon, & Site-Wide OU (B833)
Disposal:		
Permitted discharge to ambient air	VOCs	B834, B854, B832 Canyon, & Site-Wide OU (B833)
Spent GAC regeneration/disposal	VOCs	B834, B854, B832 Canyon, & Site-Wide OU (B833)
<b><u>Containment:</u></b>		
Capping	VOCs, leachable substances	Retained for consideration at landfills
<b>Surface Soil</b>		
<b><u>No further action</u> (No sampling or analysis)</b>		HEPA, B850/Pits 3 & 5, B854 & B832 Canyon
<b><u>Risk and hazard management:</u></b>		
Administrative controls:		
Fencing and signs	VOCs, Be, uranium, tritium <sup>c</sup>	B850/Pits 3 & 5, B854, & Site-Wide OU (B801 firing table, 845, 851 firing table)
Security guards/patrols	VOCs, Be, uranium, tritium <sup>c</sup>	B850/Pits 3 & 5, B854, & Site-Wide OU (B801 firing table, 845, 851 firing table)

**Table 3-7. Retained general response actions and remedial technologies.**  
**(Cont. Page 4 of 4)**

General response action/ technology		
General Response Action/Technology	Applicability to contaminants of concern (COCs)	Applicability to OUs/Release Sites
<b><u>Risk and hazard management (cont.):</u></b>		
Land use restrictions	VOCs, Be, uranium, tritium <sup>c</sup>	B850/Pits 3 & 5, B854, & Site-Wide OU (B801 firing table, 845, 851 firing table)
Ecological hazard control	VOCs, PCBs/CDDs	B834, Pit 6 Landfill, B850, B854
<b><u>Removal and disposal:</u></b>		
Excavation	All COCs <sup>d</sup>	B850/Pits 3 & 5, B854, & Site-Wide OU (B801 firing table, 841, 845, 851 firing table)
Waste disposal	TBD	Landfill Pits, as appropriate
Contaminated soil disposal	PCBs, CDDs, CDFs	B850/Pits 3 & 5 & Site-Wide OU (B801, 802, 845, 851 firing tables)
<b><u>In situ treatment:</u></b>		
Phytoremediation	Metals	B850/Pits 3 & 5, B854
<b><u>Surface Water</u></b>		
<b><u>Risk and hazard management:</u></b>		
<b>Administrative controls:</b>		
Fencing and signs	VOCs & tritium	VOCs: Pit 6 Landfill, HE Process Area, B832 Canyon, & Site-Wide OU (B833 only) Tritium: B850/Pits 3 & 5
Security guards/patrols	VOCs & tritium	VOCs: OUs Pit 6 Landfill, HE Process Area, B832 Canyon, & Site-Wide OU (B833 only) Tritium: B850/Pits 3 & 5
Land use restrictions	VOCs & tritium	VOCs: Pit 6 Landfill, HE Process Area, B832 Canyon, & Site-Wide OU (B833 only) Tritium: B850/Pits 3 & 5

**Notes:**

B834 = B stands for building.

COC = Contaminant of concern.

HE= High explosives.

OU = Operable Unit.

TBD= To be determined.

VOC = Volatile organic compound.

<sup>a</sup> COCs in ground water include VOCs, TBOS/TKEBs, HE compounds, perchlorate, nitrate, tritium, and uranium.

<sup>b</sup> COCs in the vadose zone include VOCs, HE compounds, uranium and tritium.

<sup>c</sup> See Table 1-5 for COCs present in each OU.

<sup>d</sup> COCs in surface soil include metals, HE compounds, PCBs, CDDs, CDFs, uranium, and tritium.